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INTELLIGENCE

L. L. BISCHOF

Intelligence

Statistical Conceptions of Its Nature

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Doubleday Papers in Psychology

Intelligence

Statistical Conceptions of Its Nature

By L. J. BISCHOF

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Preface

What is intelligence? An accurate answer to this question is necessary for the ultimate solution of such practical problems as: How can intelligence best be measured? How do environmental factors contribute to the growth of intelligence? How do emotional factors and specific learnings integrate with intelligence to determine the efficiency of our problem-solving behavior?

The answer to the fundamental question is not one which depends on consensus. We can argue about a definition, have it carried by the dictionary, and still be wrong. The answer must correspond to that aspect of the fundamental capacity of man which contributes to his problem-solving abilities. In search of such information many psychologists have devoted themselves to the analysis of test performances, largely by statistical techniques. The search for a theory of intelligence has often been obscured by the practical values of the tests developed on the basis of assumptions (explicit or implicit) or hypotheses concerning its fundamental nature.

The present paper reviews the development of theories of intelligence. It helps us attain perspective by concentrating on the fundamental question, What *is* intelligence? Is it one factor? Is it a set of group factors? Is it a series of specific factors without anything in common? Dr. Bischof, the author of this paper, has undertaken to clarify the variety of theories offered by developing a series of ingenious graphic aids. Systematically presenting charts, he takes up theory after theory and identifies their salient elements in a form that makes it easy to compare one with another. The use of charts eliminates the involvement of elaborate statistical presentations.

Thanks to this survey of the major theories of intelligence it will be easier to appreciate the limitations of many popular conceptions and to realize some of the help modern psychology can contribute in the solution of a variety of applied problems, both personal and social.

EUGENE L. HARTLEY
Consulting Editor
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Contents

section one

Background for the Study of Intelligence

If we were to gather definitions of intelligence we might find as many as fifty or more, depending upon how zealously we looked for them. Some of these definitions consider intelligence a capacity, some an ability; some emphasize learning, some applying previous learning, some the perceiving of abstract relations; some definitions insist on the innate character of intelligence, others avoid the question.

Let us use for the present the following definition: "Intelligence is the ability to solve problems of *all* kinds." Admittedly this is a very general definition and possibly a loose one. However, if we were to collect all the definitions and sift out the concepts that they have in common, we would find the problem-solving concept involved in all but a few, or in the application of the definitions in a concrete situation. It should be understood that "problem-solving in all situations" includes academic problems, social problems, personal problems, and the rest.

It is not our intent at this time to produce still another definition of intelligence, but rather to present a workable point of departure so that we may proceed on a common basis. Since all of us possess some degree of intelligence or mental ability, the study of this is potentially interesting. It is in a sense the study of ourselves relative to our problem-solving abilities.

The most useful method of measuring intelligence derives originally from the work of Alfred Binet. Binet was an official of the school systems of Paris. In his position he received many complaints from schoolteachers regarding the differences in mental capacity of their students. These differences resulted, as far as the schoolteachers were concerned, in a difficult teaching situation. The few slow learners thwarted the efforts of the teacher and also of the class, while the few fast learners were chafing at their slow rate of progress. Indeed are not these same problems still present in the schools of today?

Binet sought to discover a device or a method by which the slow and the fast learners could be identified *before* they were put through the unhappy

experience of failing in their school work or—equally bad—losing interest because the work was far too elementary for their mental abilities. Binet's method was actually very simple, but for its time a unique advance. Binet constructed many problems which required mental ability. In accordance with his conception of the components of intelligence, the problems were designed to reveal (1) the tendency to take and maintain a definite direction, (2) the capacity to make adjustments in a plan of action to overcome obstacles and achieve a goal, and (3) the power of self-criticism. With these problems he went about France and tested many children. His main purpose was to establish the average of performances on each mental test by school children of each age. Thus if the test required remembering digits (for example, 6-8-3-2 or 7-4-1-6-2-9) he would ask all the available six-year-old children to repeat as many digits as they could after hearing them said once. In this way he was able to establish what the average number of digits is that most six-year-old children can remember upon one hearing. He went on to establish an average or norm in digit memory for seven-year-old youngsters, eight-year-old youngsters, and so on.

In the Binet tests there were many such tasks as memory for digits. Binet assigned credits in terms of mental age for each of these activities successfully carried out. The final result was reached by adding together all of the mental-age credits and so establishing a mental age for every child who had taken the test. Finally Binet published the result of his work as a test in 1905.

It was not Binet but Stern (whose theory of mental ability will be discussed later) who thought up the idea of intelligence quotients—the now well-known initials I.Q. Stern reasoned that since the mental age and chronological age are equal for normal children, a ratio therefore exists. He expressed it as $\frac{MA}{CA}$, which would equal the intelligence quotient (I.Q.). Early work with this formula soon became bothersome because of the decimal point. To remove the necessity of dealing in decimals the result was multiplied by 100. Thus we now have the traditional formula, $\frac{MA}{CA} \times 100 = I.Q.$

Time has been taken to elaborate slightly on the work of Binet and the expression of his test results in terms of I.Q. for two reasons: (1) We owe much to the genius of Binet for constructing a method of measuring intelligence which is still used in many mental-ability tests. (2) The concept of I.Q. is by now so firmly entrenched in the discussion of mental ability that one may hardly approach such a discussion before some thought is given to this basic concept.

Difficulties Inherent in the Traditional I.Q. Concept

The term I.Q. has become a part of everyday speech. Many people even call all intelligence tests "I.Q. tests." In many ways the intelligence quotient has proved to be of great practical value. However, as we have learned more about the nature of intelligence, the limitations of the I.Q. have been recognized, and the possibility of devising even more useful indices has become clear. Many psychologists and others interested in the mental capacity of children have become dissatisfied with a single index such as the intelligence quotient which results from the Stern-adapted Binet technique. A single number seems inadequate to reflect the varieties of mental capacities we all have. Four of the more pertinent criticisms of the I.Q. can be set forth as follows.

1. The late Carl C. Brigham remarked that no person has ever completely proved that it is "legitimate" to compile "such heterogeneous performances." He is, of course, referring to the practice of putting together such unlike items as solving arithmetic problems, working through a maze situation, and remembering digits. These items, frequently selected only because they have occurred in other mental tests, are brought together and labeled as an intelligence test, and the results are stated in terms of an I.Q.*

2. The Thurstones (whose mental-ability theory is discussed later) have also doubted the wisdom of using the I.Q. as an all-inclusive term for mental abilities. "The error that is frequently made is that the intelligence quotient is sanctified by the assumption that it measures some basic functional unity, when it is known to be nothing more than a composite of functional unities."†

3. Another source states, "The one big drawback of the I.Q. as a measure of the child's mental ability is that it tells us nothing of the *kinds* of mental tasks he excels in, nor the areas in which he is weak. Another disadvantage is that a single score can too easily become a permanent tag. It is used to explain any—or all—of the child's educational problems."‡

4. One of the past presidents of the American Psychological Association, Dr. H. E. Garrett, recognized a need for changing to some other method of considering our mental ability in more than a singular sense. In his speech in 1946 before the A.P.A. he stated, "It would seem theoretically more defensible and more useful to measure verbal, numerical, perceptual

* Crawford and Burnham: *Forecasting College Achievement*, p. 78.

† Thurstone and Thurstone: *Factorial Studies of Intelligence*, p. 8.

‡ Thurstone and Byrne: *Mental Abilities of Children*, p. 28.

or spatial ability, and perhaps other factors at these ages than to give the subject a single over-all score." Later, in discussing the Thurstones' theory, detailed explanation will be given of the verbal, numerical, perceptual, and spatial abilities of which Garrett speaks.

A larger list could be compiled to indicate the limitations of the traditional I.Q. concept. These few are sufficient at this point to prepare the ground for further explorations into the whys and wherefores of our problem-solving minds.

Other difficulties emerge from our efforts to measure intelligence. Although the emphasis of this paper is on considering the best means of replacing the all-inclusive I.Q. with a more usable method of describing mental ability, other stumbling blocks certainly exist.

For example, we all wonder how much of our intelligence is inherited and how much of it is due to environmental influences. To deal with this question is indeed a weighty undertaking that would need an entire chapter of its own even to approach an adequate answer. Still we are curious about what we are born with. Can we change it? Should we thank our mothers and our fathers for what intelligence we possess or should be condemn them? The controversy has been named by some the "nature-nurture" problem. Literally millions of words have been written about it. The research, the multitude of explanations, and the considerations given to the problem are valuable; but is the deep controversy worth while? Would it not be just as fruitful to ask a student to clap his hands together once and then ask him, Which hand made the noise? Was it the right hand or the left hand? It matters not which hand, but how much noise resulted. How hard did the student *want* to clap? Are his hands bigger than those of another student? Could he clap just as hard on each and every occasion? All these questions coming out of our hand-clapping analogy may equally well be asked about intelligence and especially the *measurement of intelligence.*

It is the measurement of intelligence that presents our most difficult task. Again, this question, like the nature-nurture controversy, needs far more space for discussion than we have available here. It brings in questions of validity (Are we actually measuring what we hope we are?) and reliability (Can we get the same results every time?). Both validity and reliability in relation to mental measurement are beyond the scope and intent of the present effort.

section two

Theories of Intelligence

Returning once more to our main thesis, that the I.Q. expressed as a single score has many faults, we must seek for other ways of indicating our mental ability.

We are now at a point where we can consider how the theories of intelligence have developed from a single index (the I.Q.) to multiple indexes (apropos of Garrett's A.P.A. speech).

Oddly enough, most of the theories about intelligence may each be identified with the name of one person. As usual, there is an exception: a theory linked with a husband-and-wife team. Louis and Thelma Thurstone have contributed equally to their theory of primary mental abilities. With this case included, the men most easily recognized for developing theories of intelligence are: Stern, Spearman, Thomson, Thorndike, and the Thurstones.* Not always can theories be labeled so conveniently with a man's name. Such labels should make these much easier to recall than theories whose names are made-up terms and phrases which lack so completely the human touch.

The Chinese are credited with saying that a picture is worth ten thousand words. If this is true then a drawing should also be valuable. All of the theories here introduced have been made graphic by drawings. Perhaps by means of them we may save words and create a clearer picture of just what the theories of intelligence are. This method has been employed because it allows us to present a very complicated statistical theory in an uncomplicated way. There is, of course, the danger that in simplifying an involved

* The valuable and sometimes intuitive work of David Wechsler has not been included. It is felt that an adequate exposition of theories of intelligence may be given without the Wechsler-Bellevue approach. Wechsler's book, *Measurement of Adult Intelligence* and his test (both adult's and children's forms) are more concerned with measurement than theory, although Wechsler has an excellent chapter, "The Nature of Intelligence," wherein he indicates that he feels that the work of Spearman marked one of the greatest discoveries in psychology (p. 6). Hence, by our discussion of Spearman's theory we may also be including the theoretical basis underlying Wechsler's test.

statistical view, loose generalizations may be risked; however, if the reader gains a clearer understanding of intelligence theories and if no errors are committed, the risk has been worth while.

Stern: Uni-factor Theory

Around 1911 Wilhelm Stern introduced his *uni-factor* theory of intelligence. This theory has also been known as the *general capacity* theory. Stern's idea probably grew out of the work that Binet had just completed. At least he was well enough aware of Binet's approach to have constructed the I.Q. ratio previously mentioned.

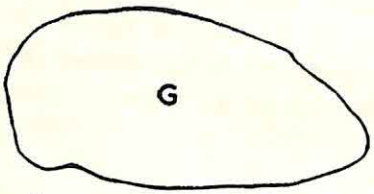


FIG. 1. Stern's uni-factor theory of intelligence, showing intelligence to consist of only a general capacity, G.

According to Stern intelligence is a general or unitary ability. This single ability has been labeled G in Figure 1. The contours of the drawing have deliberately been made loosely rounded in order to indicate the shapeless, difficult-to-define characteristic called intelligence. Although Stern so far as we know left no drawing such as this, it does present his unitary idea.

The amorphous character of intelligence would never have the same size, or indeed the same shape, from one person to the next. This concept of individual differences has a modern ring to it. We might not agree totally with Stern's uni-factor theory, but we must agree that in amount of intelligence people are certainly different one from another. Just from every day experience we discover that no two people ever seem to think, act, or solve problems in exactly the same way and at the same level of difficulty.

In Stern's view the amount of G (general capacity) that an individual possesses could be directed toward any activity. G, therefore, concerns itself with *any* problem-solving situation, whether involving memory or space or mathematics. Our general capacity, G—in whatever amounts we possess, naturally—could solve a multitude of problems.

The question naturally arises, Can a given person solve one certain type of problem better than other types? Stern's answer was yes. The person's environment would determine the activities in which he would excel.

Stern considered *all* persons, then, to be born with G, though in unequal amounts; efficiency in applying it depended solely upon their environments.

For example, people may have unequal amounts of ability to solve mathematical problems. John may have been born with a smaller amount of G than Fred, but through advantages in his environment his performance in solving mathematical problems could be far greater than Fred's. We may assume that it will continue to be so, at least until Fred also receives training or an environmental advantage equal to John's. Then Fred will surpass John in mathematics.

There is an over-all sense of agreement in the definitions and explanations embodied in other general-capacity theories of intelligence, although not all the general-capacity theorists may be inclined to concede this.

Stern's theory, then, is the simplest because it has only one factor. Though the most elementary, it is not without difficulties when we consider the nature-nurture side of the question, discussed in the preceding section.

Spearman: Two-factor Theory

Charles Spearman was a British-born mathematician who became interested in the intelligence of man. In 1904 Spearman proposed a *two-factor theory*. The first factor is very much like Stern's general capacity. In fact the relationship between the two men's theories has been emphasized by using the same letter (G and g) in Figure 1 and Figure 2 to denote a general capacity of intelligence. But Spearman, unlike Stern, worked out by statistical methods additional capacities, which he called *s* for "specific intelligences."

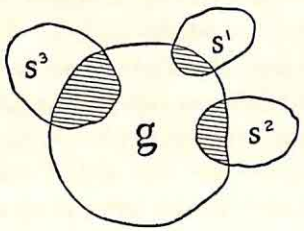


FIG. 2. Spearman's two-factor theory, with a general capacity (*g*) and three specific kinds of intelligence (s^1, s^2, s^3).

Figure 2 illustrates the original Spearman two-factor theory; in it the letter *g* represents general intelligence. Growing out of this g are three smaller shapes labeled s^1, s^2, and s^3. Spearman called these the *specific intelligences*. Describing the *s* factors as growing out of the *g* factor is quite accurate, because that happens to be the way Spearman's statistical methods moved. He began with the *g* (general capacity) and then discovered that

by statistical methods he could extract s's (specific intelligences) that were not like a general-capacity intelligence *in most respects*. Thus Spearman's investigations proceeded from a g factor out to s factors.

In Figure 2 the unshaded portions of s^1, s^2, and s^3 represent specific kinds of intelligence that are not similar to the general factor. That portion of the specific intelligence which is similar to the general factor is indicated by shading. The reader will notice that s^1 and g share a common shaded area smaller than that shared by s^3 and g. This difference is intentional and shows that s^1 is more independent of g than is s^3.

There is a reason for drawing each one of the s factors in a slightly different size and shape. It indicates that within one person none of his specific kinds of intelligence are the same. Going one step further, we may also state that no two people ever have the same size and quality of g factor, and further, that no two people ever have the same size and quality of s factors. They would possess the same number of s factors, only the shape of the s factors would vary from person to person.

To summarize the theory of individual differences in Spearman's theory:

1. People have different amounts of g (general capacity).
2. People *within themselves* have different amounts of each s factor (specific intelligences).
3. People are different in the amount and kind of g and s factors they possess.

Spearman gave no definite names to the g or s factors at this point. He preferred to hypothesize the g factor as the general mental energy an individual possesses. The s factor would be the engines or neural patterns through which the g factor operated.*

Spearman did not stabilize his ideas, however; being a thorough statistician, he continued to refine his correlation techniques and methods. Figure 3 pictures the final result of Spearman's brilliant pioneering in the field of mental organization.

In Figure 3 we have two new areas, s^4 and s^5, added to the drawings of Figure 2. Figure 3 summarizes the final work of Spearman.

Upon inspection we see that something new has been added by the overlapping of s^4 and s^5. This creates two new areas: the crosshatched area which is now shared by the g factor and the s^4 and s^5 factors, and the black area which only s^4 and s^5 share in common.

Spearman never clarified the meaning of the area seen in crosshatched form. We can only conjecture as to its significance. Perhaps had he con-

*As will be seen later, the concept of neural patterns is also a major one in Thorndike's multi-factor theory.

tinued to refine his statistical techniques, a newer drawing would show only crosshatched areas and solid areas. Certainly these areas became more and more pronounced as his work progressed.

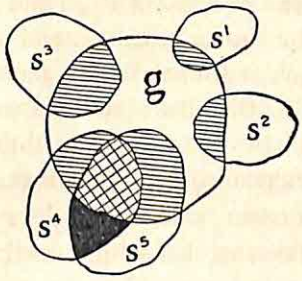


FIG. 3. Spearman's two-factor theory showing a general capacity (g), five specific intelligences (s^1, s^2, s^3, s^4, s^5), and a group factor (black area).

It is, however, the solid area shared in common by s^4 and s^5 that now emerges as important. (The figure shows only one solid area, though of course other solid areas exist.) Spearman at last gave names to his ideas of such areas. The solid area he called a *group factor*, and he recognized five group factors. He and the advocates of his theory named them verbal ability, numerical ability, mechanical ability, attention, and imagination. A possible sixth ability was tentatively called mental speed. Spearman later suggested three additional nonintellectual areas which needed further research before they could be called identities in their own right. These three he named and labeled perseveration (P), oscillation (O)—that characteristic we all have of varying in our performance during prolonged mental work—and a will factor (W). The last-named factor was described as persistent effort. Upon scrutiny this sounds very much like the perseveration (P) factor, although Spearman did not consider them to be similar.

Thus, we see that the theories about intelligence have progressed from the theory of a single "something" (Stern) which represents our problem-solving ability, to a more complicated theory (Spearman) which presents our intelligence as consisting of general abilities plus at least five specific abilities.

Let us turn our attention now to a theory which runs counter to the two theories of Stern and Spearman.

Thomson: Sampling Theory

Godfrey H. Thomson first proposed in 1916 a *sampling theory* which was in direct contrast to the theories of Stern and Spearman. Thomson later clarified his theories in 1935 and still later in 1948.

Studying the problem, again as a statistician, Thomson used a clever and unique approach. By the throwing of dice and the random selection of cards, his study of purely chance selection indicated that any given mental test may sample a number of independent abilities. The statistical techniques and philosophy of chance selection are far too complex to describe at this time, but Thomson's idea was to show that test items should be selected by chance rather than by the method of purposive sampling which Binet and Spearman had used.

Two mental tests, therefore, will have a high or a low correlation only in so far as there is more or less "commonalty" among the underlying elements tested by each. Thomson did not exclude the possibility that a g (general ability) factor might exist. But he felt that this would be a special case of group factors.

To get a clearer understanding of Godfrey Thomson's sampling theory of intelligence let us examine Figure 4.

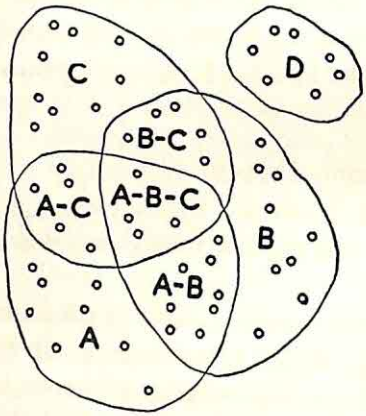


FIG. 4. Godfrey Thomson's sampling theory of intelligence, with small circles to represent independent mental abilities and circles *A*, *B*, *C*, and *D* to indicate tests.

At first glance the drawing seems complicated by numerous small circles, but careful attention may isolate certain main ideas of Thomson's work.

It may readily be seen that the above diagram contains no over-all g factor such as we found in the theories of Stern and Spearman.

In the drawing each small circle represents an ability independent of other abilities. From the relatively large number of circles we may assume that more independent specific abilities exist, for example, than Spearman indicated. Each of these specific abilities, however, enters into a factor of greater breadth.

The larger circles indicated by the letters *A*, *B*, *C*, and *D* are intended to represent mental tests. For example, Test A deals with a total of twenty-five abilities, or twenty-five small circles. Of the twenty-five abilities tested in Test A it shares eight with Test B, five with Test C, and four with Tests B and C together. Thus in Thomson's view if a *g* factor did exist, it would probably be those four abilities which Tests A, B, and C test in common.

The same relationship could be traced for Test B, which deals with nine abilities exclusive to itself, but shares eight with A, five with C, and the afore-mentioned four abilities with A and C together. Likewise may we isolate nine abilities for Test C, and so on with Tests A and B.

In contrast to this we have Test D, which shares no abilities with the other tests shown in Figure 4. For example, Test D may presumably measure a physical characteristic such as strength, in comparison with Tests A, B, and C, by which abilities of verbal, mathematical, and space comprehension might be measured.

Thomson's theory presents an interesting insight into our problem-solving abilities. It is, however, highly theoretical, since so few tests have been given to individuals. The idea has been based primarily on theoretical considerations.

Thorndike: Multi-factor Theory

Somewhat similar to Thomson's theory is that of Thorndike. The similarity lies in the fact that neither theory contains a *g*, or general-ability concept.

Edgar Lee Thorndike, famous American educational psychologist, did much work in evolving a theory of intelligence. His theory too grew out of statistical procedures, but it also contains a neurological basis about which more will be said later. Thorndike's concept of intelligence has been called the *multi-factor theory*.

Dating his theory proves to be a difficult task, for other writers have given dates as widely separated as 1905, 1914, and 1926. During the course of his very vigorous career, Thorndike modified his theory from time to time as new data and new insights became available.

The graphic presentation of the multi-factor theory is given in Figure 5.

To produce an adequate drawing in Figure 5 of Thorndike's hypothesis, one would be compelled to continue drawing columns to infinity. Thorndike felt that our intelligence consisted of a multitude of highly specific processes which he did not name but which he indicated could be referred to the neurological processes.

A mental act would constitute an infinite number and an infinite com-

bination of neural connections as the impulse traveled through our nervous system. In Figure 5 each connection, or better yet, each combination of connections among the nerve cells used for our specific mental act is shown as a column. Notice that the columns are all of different heights and differing widths. This lack of uniformity indicates that the number of neural connections involved is possibly never the same for any two mental acts. It also is intended to portray that there are levels of difficulty in mental acts. The wider the column, the greater is the number of neural connections involved. The higher the column, the more complicated is the mental act.

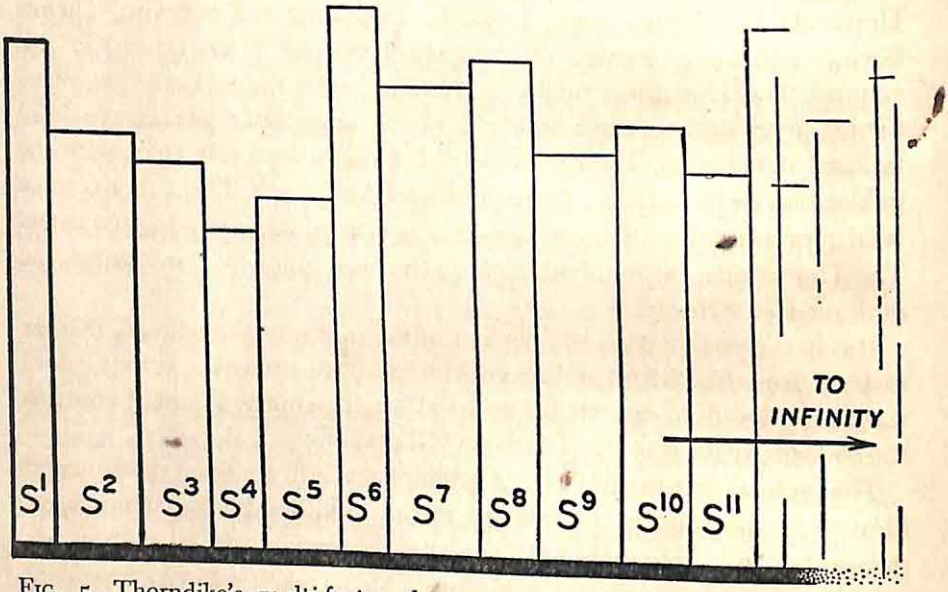


FIG. 5. Thorndike's multi-factor theory, indicating a multitude of specific neurological connections approaching infinity.

In Thorndike's view, then, general ability, the g factor of intelligence, does not exist. There exists only a multitude of specific mental acts defined only in terms of the psychologist's capacity (1) to discover how many nerve-cell connections exist and (2) to classify them according to the level of difficulty of the problem being solved by the mental act. For example: adding 2 and 2 would require fewer nerve-cell connections (a low column in Figure 5) than adding 2 and 4 and then dividing by 3 (a higher and also wider column in Figure 5).

Thorndike himself recognized how highly theoretical some aspects of his multi-factor theory are. Turning to a more practical aspect of measuring abstract intelligence, he devised a test named CAVD after the initials of

its components. The four letters stand for sentence completion (C), arithmetical reasoning (A), vocabulary (V), and following directions (D).

In his later writings Thorndike suggested that there might be three *kinds* of intelligence: (1) *social* intelligence, or dealing with people, (2) *concrete* intelligence, or dealing with things, and (3) *abstract* intelligence, or dealing with verbal and mathematical symbols. The CAVD is an example of a test of abstract intelligence.

Thurstone: Primary-Mental-Abilities Theory

A separate section might have been devoted to the work of the former University of Chicago team, Louis L. Thurstone and his wife, Thelma Gwinn Thurstone, because of the general interest it has created in this country. The Thurstones might be classified under the unusual title of statistical psychologists, since they are at the same time psychologists and brilliant statisticians. Their work dates from approximately 1938, with the publication of the article, "Primary Mental Abilities."* This title has since been appropriated for the intelligence tests now published under that name. The Thurstonian theory of intelligence has been called by many writers the *multiple-factor theory.*

It is in the presentation by drawings of the multiple-factor theory that we may be prone to overgeneralize in attempting to present a very involved statistical procedure in a simple and forthright manner. Figure 6 contains the elementary ideas of the Thurstones' theory.

The unusual drawing in Figure 6 attempts to indicate three fundamental ideas: (1) the *number* of primary mental abilities in the Thurstones' theory, (2) the *relationship* each one of these primary mental abilities has to every other primary mental ability, and (3) the *relationship* each primary mental ability has to a general mental ability. We shall discuss the fundamental ideas in the above-mentioned order.

Number of primary mental abilities. Examination of Figure 6 reveals seven separate primary mental abilities: number, word fluency, verbal meaning, memory, reasoning, space, and perceptual speed. Actually the seventh ability, perceptual speed, had not been definitely established by the Thurstones in their original research. It has been included here because it appears to hold some promise for future testing. A fuller explanation of the seven abilities will be undertaken later in this section about the Thurstones.

In contrast with Thomson's method of selecting components of a test for intelligence by card drawing and dice throwing, the Thurstones arbi-

* L. L. THURSTONE: "Primary Mental Abilities." *Psychometric Monographs*, No. 1, Chicago, University of Chicago Press, 1938.

trarily chose sixty subtests for examination. The examination was done by an involved statistical technique called factorial analysis. Through the use of this method they refined the sixty subtests down to twenty-one. However, in the test which is sold commercially to psychologists, only eleven tests are used to measure our primary mental abilities.

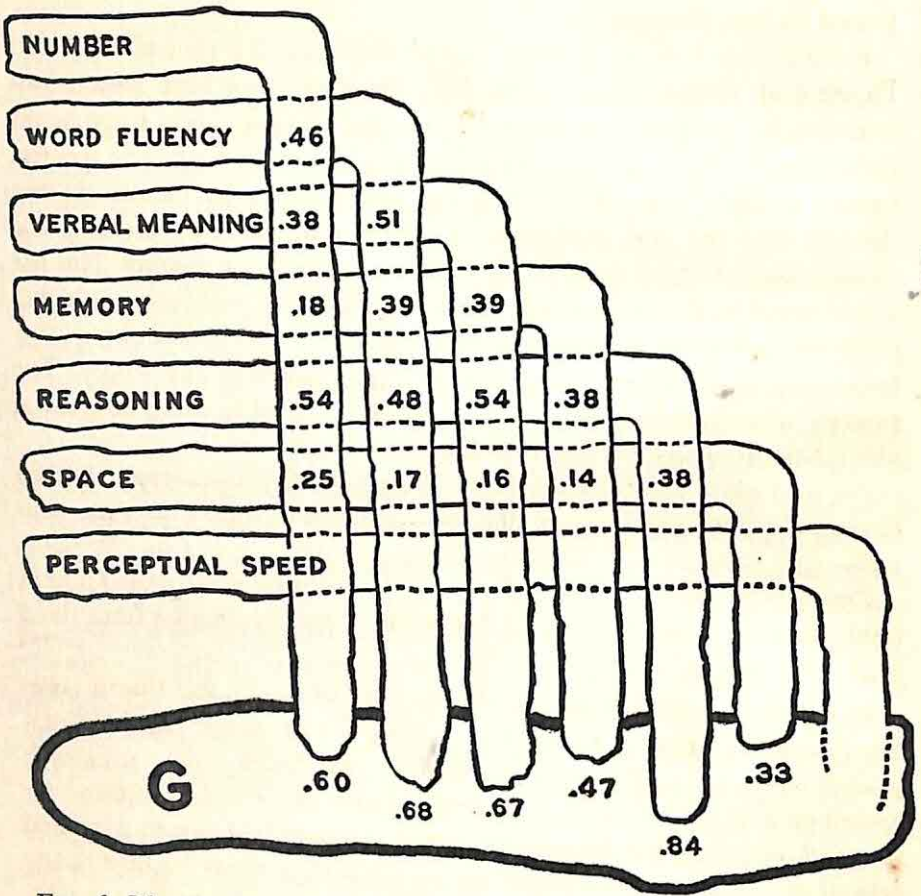


FIG. 6. Thurstone's multiple-factor theory, with primary mental abilities related to each other and to a general capacity.

Relationship between primary mental abilities. Each primary mental ability in Figure 6 has been drawn so that it intersects each one of the other primary mental abilities. This intentional crossing of the abilities signifies that they are related to each other in some positive way. Within the intersections are numbers. These numbers are the coefficients of correlation between the abilities so involved. Thus, the two sets of mental abilities which

are most like each other in relationships are reasoning with number and reasoning with word meaning. Both correlations are .54 in these cases. The two mental abilities which are most unlike in relationships are space and memory, whose correlation is .14.

No correlations have been given for the relationship of the perceptual-speed mental ability to the other mental abilities because none were reported by the Thurstones.

Relationship between primary mental abilities and a general ability. In Figure 6 all of the primary mental abilities, after they have been drawn horizontally, are turned downward to proceed vertically so as to go across each other, and then are incorporated into a larger area marked G (general mental ability). The reader will notice that the primary mental abilities descend into the area marked G to different depths. For example, the primary mental ability most highly correlated with G is reasoning. This has a correlation with general mental ability of .84. There is therefore a higher relationship between reasoning and general mental ability than there is between any other primary mental ability and general mental ability. The primary mental ability with the least amount of relationship to general mental ability is space. This correlation is only .33.

No correlation has been shown for the relationship of perceptual speed to general mental ability, since none was reported in the Thurstones' writings.

Correlations shown in Figure 6 are not likely to be exactly the same as result from other studies using the test scores of people different from those used in the original research.

In regard to general mental ability, G, the Thurstones feel that it raises the interesting question whether a "unique general factor can be determined." This is an illuminating statement and causes one to wonder if Spearman and his followers, with their g factor and s factors, are too far removed from the Thurstones' seven primary mental abilities with a residual general mental ability. The reader may recall that Spearman began with the premise that there was a general factor. He then refined his methods to discover later that special factors could be taken out of the general factor. Now we have the Thurstones, who began with the supposition that primary mental abilities existed and proceeded to wind up with some kind of general mental ability. In some ways there is a good deal of similarity between the two theories. The differences may only be differences of approach, one theory going from general to specific (Spearman), the other going from the specific to the general (Thurstone).

The interpretation of the Thurstones' theory would be that the primary

mental abilities are correlated by a general factor which would operate through each of the primaries. Each of the primary mental abilities is to be regarded as a combination of an independent primary ability and a general ability. The primary abilities share the general mental abilities with each other. The Thurstones felt that the psychological interpretation of the general mental ability was only tentative.

Describing the Primary Mental Abilities

Because the work of the Thurstones is becoming more widely known and because we might be able to understand our own intelligence better through a better understanding of these abilities, a brief description and an example of each of the seven primary mental abilities are now appropriate. They will be discussed not in order of importance—since to determine their relative importance to each one of us is an impossible task—but in the order in which they were listed in Figure 6.

Most of us have these abilities in fairly equal amounts. But, (just as in Spearman's theory) no one appears to have exactly the same amount of all seven mental abilities. Each one of us is different from every other in regard to the amount we have of each of the primary mental abilities. As each primary mental ability is described there may be a slight tendency to imagine that it is more important than the others. This is not the case. Emphasis is only for illustrative purposes.

(1) NUMBER. This is the ability we use when we add, subtract, multiply, and divide and do it quickly and accurately. It is not the same as reasoning ability, because it involves only the four fundamental arithmetic processes. When we solve problems in arithmetic we must, it is true, have number ability, but reasoning must also take place if we are to know which of the four processes to use and especially in which combinations.

For example, the cashier at the chain grocery store is using number ability but has little need for reasoning ability as she ticks off the items of food. Another example is the bookkeeper who manipulates figures in a prescribed manner. This is number ability. The accountant, however, who not only is adept with figures but must reason out the system of bookkeeping to use is employing more than straight number ability.

Some of us are unfortunate in not having very much of this ability. Drill and hard work may help us to use what we have more efficiently, but it can not aid us in adding bowling scores or golf scores, or figuring baseball averages in quick time and without errors. Fortunately for us, there are mechanical calculators to do much of this work.

(2) WORD FLUENCY. Those of us who have large amounts of this ability

can write and speak with considerable ease. The salesman, the carnival barker, and the fast-talking sports announcer are all gifted with this primary mental ability, as well as the hack writer who pounds out innumerable stories on his typewriter.

It does not, however, necessarily go hand-in-hand with verbal meaning, the next of the primary mental abilities. There are many students who have seen this demonstrated when professors who may be very learned in their fields—may have large vocabularies—hem and haw through many a lecture that proves to be dull and full of "ah's" and "uh's."

We do not mean to imply by the above definition of word fluency that a person does not know the meaning of what he is saying. He simply uses the words he knows in a quick manner and with no hesitations.

(3) VERBAL MEANING. This is the understanding of ideas expressed in word form. Students who excel in this ability are interested in words; their similarities, differences, and definitions. These are the students who read easily and love to do it. They enjoy reading and writing poetry. Crossword puzzles, no matter how difficult, are fun for them, and they enjoy the challenge of getting the word "exacerbate" correctly when defined as "to irritate."

A higher education is so tremendously dependent on this ability that all of us are apt to misclassify the nonverbal student as stupid. This is a grave error if he possesses a high degree of many of the other primary mental abilities and is short on only the verbal one. Such an unfortunate failing student is attempting to compete in a contest to which he brings the wrong set of equipment.

(4) MEMORY. To the casual reader it may seem odd that this ability is considered to be separate from the other primary mental abilities. Is it not logical to assume that we can not exercise our number ability unless we *remember* the numbers and fundamental processes? And how can we use our vocabularies in speaking and in reading unless we can *remember* what the words mean? To answer these questions we must consider at least two points: (a) All of the primary mental abilities are related to memory to some extent. This fact we discovered in our examination of Figure 6. (b) Memory is also related to the G (general mental ability) factor, the correlation being .47. Consequently, we cannot consider that the other mental abilities exist entirely independent of the memory factor.

(5) REASONING. The student who has much of this ability can solve complex problems, profit from experience, and plan new activities based on the consequences of the past. College training depends a great deal on this ability. The higher you progress along the educational ladder the more

reasoning ability you will need. Large amounts of reasoning ability are necessary in studying science courses and mathematics.

Referring once again to Figure 6 we see that this ability has the highest correlation with general mental ability (G). It is also more closely related to the other primary abilities than they are to each other.

(6) SPACE. Have you ever watched the skilled mechanic reach into his box of tools and bring out the correct-sized wrench just by noticing the size of the nut and matching it visually with the size of the proper wrench? This is an example of space mental ability.

Draftsmen also use this ability when they draw a figure in two dimensions —vertical and horizontal—but can imagine and draw the lines that would indicate the third dimension, depth. Among occupations which demand high levels of space ability are those of architects, artists, pilots, carpenters, designers, and machinists.

(7) PERCEPTUAL SPEED. No doubt at some time you have seen a picture puzzle that asks, "What's missing in the picture?" The quickness with which you can identify and supply the missing part is a demonstration of perceptual speed. In developing reading skill it is necessary to identify entire words without carefully examining each letter in the word. Thus the perceptual-speed ability becomes quite important to our school work. Those with reading and even spelling difficulties lack this ability. The letters b and d, p and q, and m and n are troublemakers for the beginning reader who lacks perceptual speed.

Vocationally it is important for the proofreader, the telephone operator, and the radio announcer who must scan and read rapidly the newscasts of the day.

section three

Implementing the Primary-Mental-Abilities Theory

In the beginning of this paper the older concept of the score usually known as an I.Q. was critically examined. It was found to be too inclusive for meaningful interpretations of our intelligence. The I.Q. does have value in that it can give an over-all idea of intellectual ability, and it has existed long enough to be generally understood by the public at large. Nevertheless it conceals more than it reveals. It labels more than it enlightens. It is becoming a historic method of indicating intelligence. To replace this method let us turn our attention to the use and importance of the theory of primary mental abilities.

Everyday experience with the mental abilities of those we contact as parents, teachers, or friends has frequently shown us that we all have strong points and weak points in our capacities to solve problems in many different areas. Introspection—looking in toward ourselves—also indicates that we think well and easily in some problem areas, while in others our efforts are less successful despite the expenditure of effort.

The previous section which explained and described the theory of primary mental abilities also indicated that much practical research has been accomplished by the Thurstones to validate the concept.

Educational and vocational guidance would be unnecessarily difficult if it did not utilize the primary-mental-abilities approach. It would be difficult for the counselor to aid the client in making choices for educational goals without some indications of the varying capacities each client possesses. Likewise, choosing our best vocational possibility requires knowledge of what types of abilities we possess most of. The concept of primary mental abilities enables us to determine the *quality* of mental ability as well as the *quantity*.

A Sample Test of Primary Mental Abilities

Having expended some time reading about and considering mental ability, the reader may be interested in taking a short sample test of the primary-mental-abilities type.

Your score on the sample test* is merely an indication of mental abilities and in no way should be presumed to be an accurate score. A score of five on one test and a similar score on another test may or may *not* indicate your abilities are equal in the two factors measured.

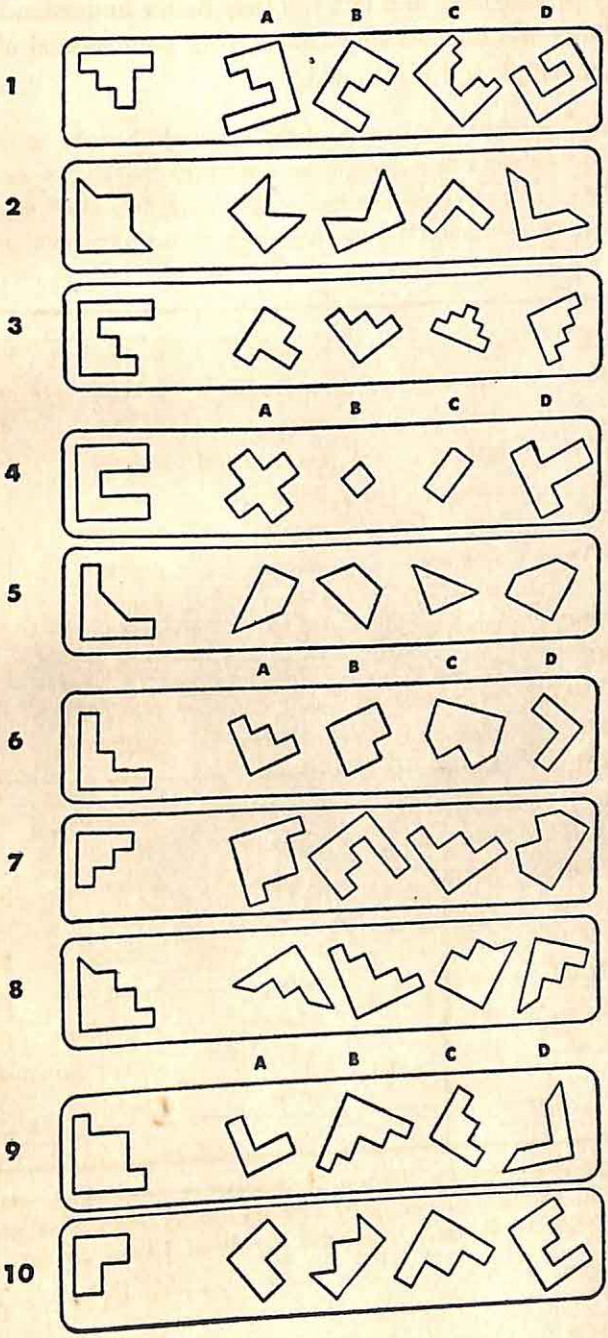
By actually participating in a test you may better understand the theory of mental ability and discover more about your own mental abilities. For this reason the sample test is included.

Verbal meaning. Here is a sample of the items which make up a vocabulary test, one of the best ways to determine how much of the Verbal meaning ability you possess. See if you can underline the word in each line which means the same as the first word in that line. (The average high school graduate gets about 15 correct.)

1	JUVENILE	awkward	youthful	dependent	bashful
2	FAMOUS	fluvial	renewed	faithful	renowned
3	OVERT	rich	open	trifling	quiet
4	WANTON	gainful	unrestrained	extensive	soft
5	REMOTE	inimical	distended	sparse	far
6	POTENT	gay	thick	tiresome	strong
7	OPULENT	wealthy	elective	contrary	hateful
8	SERE	withered	cheap	helpful	single
9	ECCENTRIC	emphasized	wary	awful	strange
10	VOLUBLE	edible	enlarged	dreamy	fluent
11	ANONYMOUS	reconditioned	destructive	nameless	synonymous
12	ACOUSTIC	melodious	auditory	seldom	ecstatic
13	INEBRIATE	kingly	weary	frisky	drunken
14	SUPERB	gilt	magnificent	immense	minute
15	FLAGRANT	notorious	patriotic	inflated	suitable
16	CAPACIOUS	hungry	savage	roomy	odorous
17	FETID	amusing	feverish	putrid	contagious
18	GROTESQUE	lively	recumbent	bizarre	tragic
19	MALIGNANT	stolid	harmful	worn	poor
20	INNATE	drunk	inherent	imperative	passive
21	PRODIGAL	lost	beloved	extravagant	young
22	FRANK	popular	queer	brutal	open

* The author is grateful for the use of this sample test, which comes from the pamphlet *Mental Abilities of Children* by THELMA GWINN THURSTONE and KATHARINE MANN BYRNE, Science Research Associates, 57 West Grand Avenue, Chicago, Ill. (50¢).

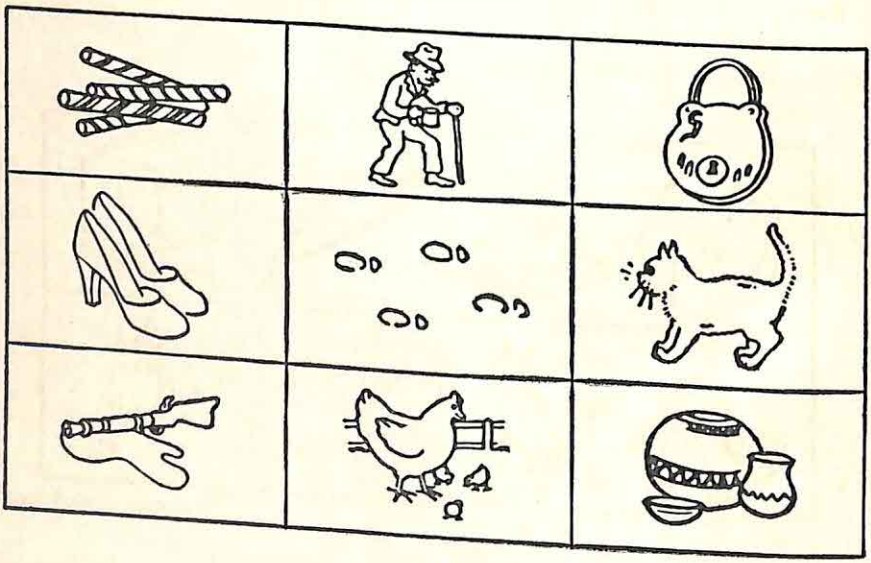
Space. Here are some samples of test items that measure Space ability. Make a square out of the first drawing in each row by adding to it one of the other four drawings in the row. In each row mark the drawing which will make a complete square of the first figure. It's speed that counts. A minute is all that you should allow yourself.

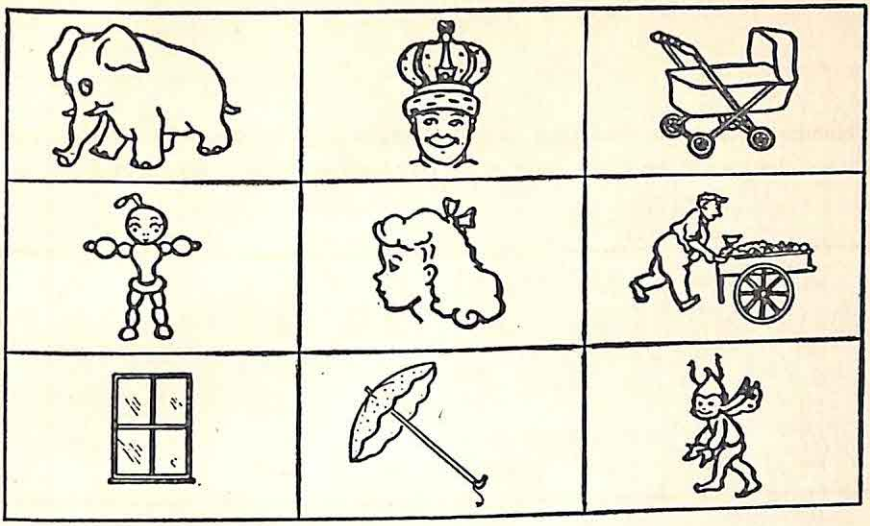


Number. If you can add these numbers without error in about 30 seconds, you may well be one of the gifted ones as far as Number ability is concerned.

68	49	67	84	69	75	56	86
34	38	43	35	56	98	78	35
90	56	86	99	82	78	84	
77	69	46	39	57	74	63	

Word *fluency*. This is a test to measure the ease with which words come to you. See whether you can name the pictures below in less than two minutes. Each name must begin with the letter P.

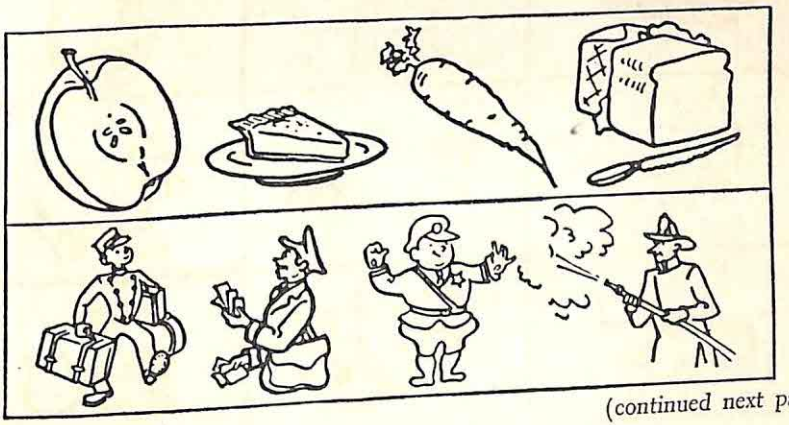




Memory. Study these names—about 15 seconds for each one—carefully, then look at the last names only on page [26], and write the first name which belongs with each one. If you can recall 10 out of 12, you probably have a good memory for such facts.

Ralph Condon	Earl Nash	George Adams	Joan Pratt
Mabel Potter	Frank Andrews	Laura Jones	Marie Lange
Betty Edwards	Grace Taylor	John Fleming	Robert Carson

Reasoning. Try these examples from a test which measures Reasoning. In each line find the way in which three of the pictures are alike, and then mark the one which is different from these three.



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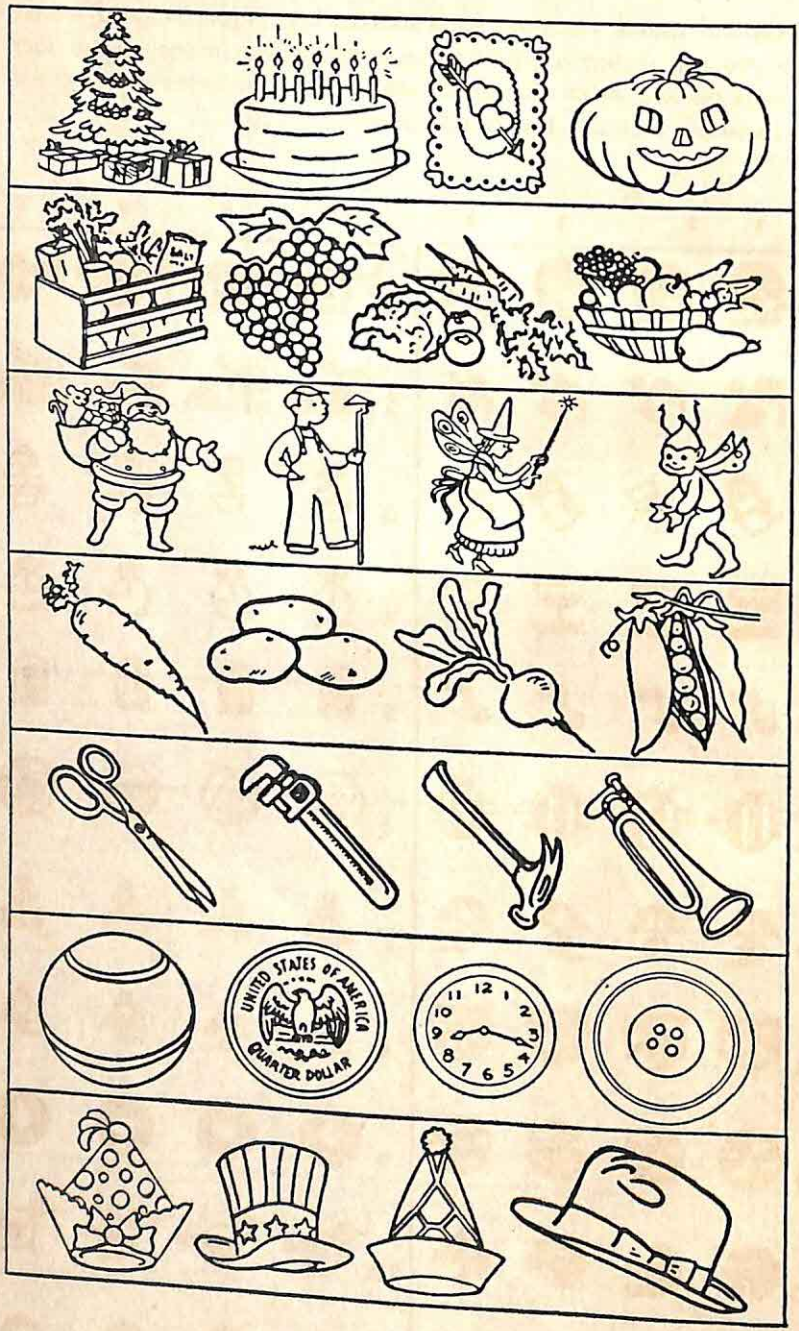
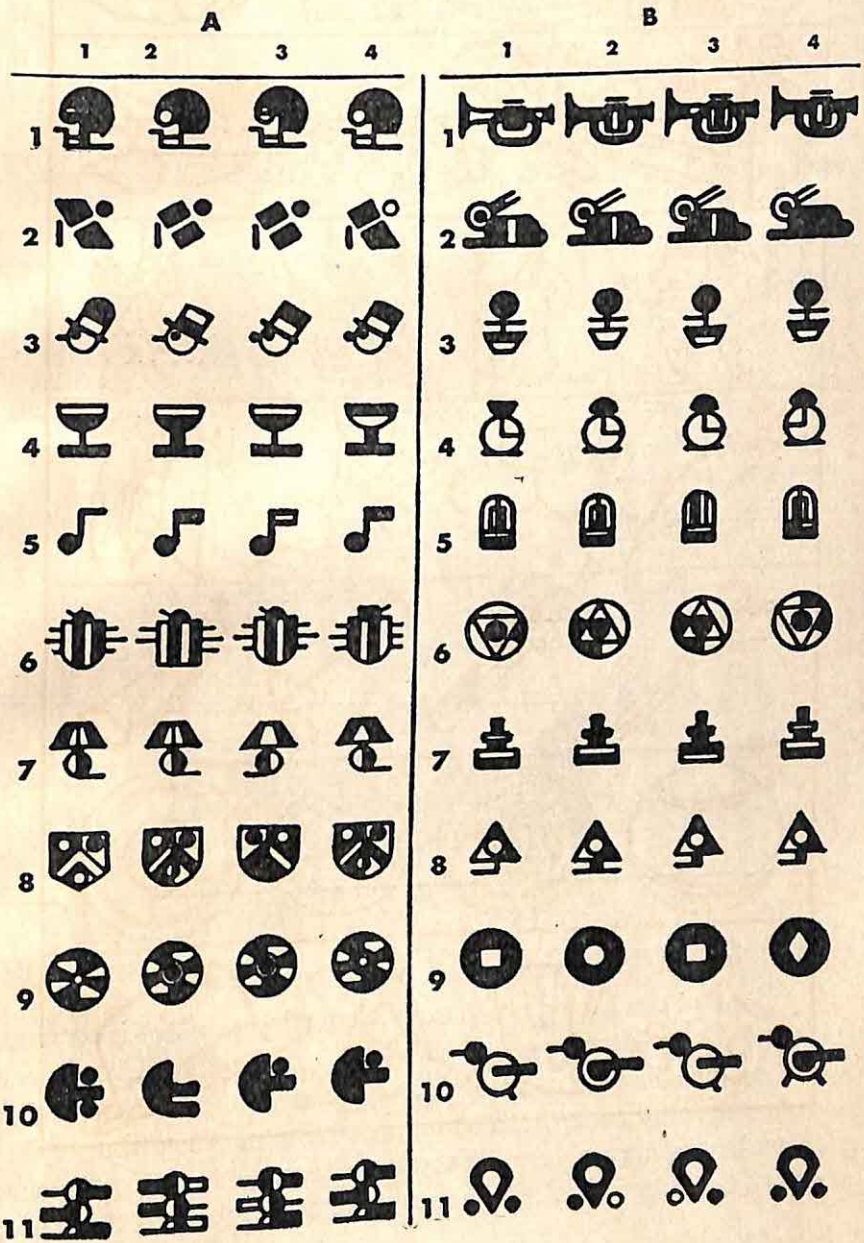

UNITED STATES OF AMERICA
QUARTER DOLLAR

Perceptual speed. Here are some samples from a test designed to see how quickly you can recognize likenesses and differences. In each set of four pictures, mark the two which are *exactly alike*. If you can do these correctly in two minutes you are probably high in Perception.



Answers to the sample test items

Verbal meaning. youthful; renowned; open; unrestrained; far; strong; wealthy; withered; strange; fluent; nameless; auditory; drunken; magnificent; notorious; roomy; putrid; bizarre; harmful; inherent; extravagant; open.

Space. 1—B; 2—D; 3—B; 4—C; 5—D; 6—B; 7—B; 8—D; 9—A; 10—C.

Number. 102; 87; 110; 119; 125; 173; 134; 121; 167; 125; 132; 138; 139; 152; 147.

Word fluency. peppermint; pauper; padlock; pumps; prints; pussy; popgun; poultry; pottery; pachyderm; prince; perambulator; plaything, profile; peddler; panes; parasol; pixie. (There are other possible "p" words which are also correct.)

Memory. (Fill in as many first names as you can remember. Then look back at page [23] and check your answers.)

.....Edwards	.....Fleming	.....Taylor
.....Lange	.....Pratt	.....Nash
.....Jones	.....Condon	.....Carson
.....Andrews	.....Potter	.....Adams

Reasoning. carrot; bellhop; birthday cake; grapes; boy with hoe; peas; horn; ball; man's hat.

Perceptual speed.

	A	B
Row 1.	2 and 4	2 and 4
2.	2 and 3	2 and 3
3.	3 and 4	1 and 4
4.	1 and 3	2 and 3
5.	2 and 4	1 and 2
6.	1 and 3	2 and 3
7.	1 and 2	1 and 4
8.	2 and 4	3 and 4
9.	2 and 3	1 and 3
10.	3 and 4	1 and 3
11.	1 and 4	1 and 4

Applications to Intelligence and Vocational Testing

The idea that our intelligence (our problem-solving ability) is composed of more than one factor has also been acknowledged by the makers of tests other than the Thurstones. In this section we shall discuss a few of these measurement instruments that are now available to us. The makers of these tests have been concerned less with theory and more with meeting the needs of a specific situation. The tests, however, are all built around the concept

that our intelligence has more than a general mental ability or measurable I.Q., and has, rather, a number of specific mental abilities.

These tests can be roughly classified into two categories: those which attempt primarily to measure abstract mental ability—an objective much the same as that of the intelligence tests; and those which attempt primarily to measure mental abilities for purposes of vocational counseling.

In the class of tests dealing primarily with intelligence we shall discuss the following: the Army General Classification Test (AGCT) and the Wechsler-Bellevue test, for adults (W-BIS) and for children (WISC).

In the field of vocational counseling we shall discuss two tests also: the General Aptitude Test Battery (GATB) and the Differential Aptitude Test (DAT). Conveniently for us, all of the tests have become associated with their initials. This should make it easier to remember them.

These four tests have been selected for discussion because they are widely used and well constructed, and especially because they are good examples of tests in their fields. They are not the only tests available, however. For those who are interested in the kinds of other tests available an excellent book exists which lists the names and other pertinent data of many, many psychological tests.*

Army General Classification Tests

During World War I the United States Army used intelligence tests called the Army Alpha, for literate soldiers, and the Army Beta, for illiterate soldiers. Once again during World War II the Army found a need for some easily administered classification test to be given to the newly arrived soldier-trainee. The Army General Classification Test (AGCT) was devised for that purpose.

Actually, the AGCT was not established as an intelligence test, but rather as an aid in the first classification of the men in terms of their ability to learn the duties of a soldier. To this end, the test was devised to measure three mental abilities, measured by the following types of test items: vocabulary, arithmetic problems, and block counting. But these three abilities were reported in a single score.

The AGCT has been and continues to be one of the most widely administered tests. It was given more than 9,000,000 times in the second World War, and the test continues to be given to all newly inducted soldiers in the present Army. A civilian edition has now been published under the same name. The test may be administered individually or to groups.

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* Oscar K. Buros, editor: *Fourth Mental Measurement Yearbook*, Highland Park, N. J., Gryphon Press, 1953.

Although the AGCT was not designed specifically as an intelligence test it has achieved that status in the results produced.

Wechsler-Bellevue Scales of Mental Ability

There are actually two tests included under this name. The adult form is called the Wechsler-Bellevue Intelligence Scales (W-BIS); the children's form is called the Wechsler Intelligence Scale for Children (WISC). Both tests are the work of David Wechsler, chief psychologist with the Bellevue Psychiatric Hospital.

Adult form. The adult form of the test was presented in 1939. It was developed in a mental hospital (the Bellevue Psychiatric Hospital) primarily for diagnosing mental defects and mental impairment in adolescents and adults. Since that time it has captured the interest of so many clinical psychologists and educational-vocational counselors that it has now become much more than a test for the intelligence of mentally ill people.

The Wechsler-Bellevue Intelligence Scale consists of ten tests of the following types:

(1) Information
(2) General comprehension
(3) Combined memory span for digits forwards and backwards
(4) Similarities
(5) Arithmetical reasoning
(6) Picture arrangement
(7) Picture completion
(8) Block design
(9) Object assembly
(10) Digit symbol

There is an alternative test—a Vocabulary Test. The number of subtests given may be reduced to seven on certain occasions, but the full battery of ten tests is recommended for best results. The test can be given to only one person at a time.

The ten tests are combined to produce four scales, of which three are of interest to us:

(1) A verbal scale (Tests 1 through 5)
(2) A performance scale (Tests 6 through 10)
(3) A full scale (all of Tests 1 through 10)

A great deal more could be written about the adult form of Wechsler's test, but the main reason for including it here is that it exemplifies a popular individual intelligence test that has some aspects of mental-ability testing in it. The test results, however, are reported in terms of I.Q.'s; one for

the verbal part, one for the performance part, and a total I.Q. score for the combined parts.

Children's form. In 1949, ten years after the adult form was published, Wechsler presented the Wechsler Intelligence Scale for Children (WISC). The preparation and construction of this test was very carefully done. It grew naturally out of the success of its predecessor the Wechsler-Bellevue Intelligence Scale.

The WISC consists of ten tests (with two alternatives) which are very similar in nature but *not* in difficulty to the tests in the W-BIS. Like the adult scales, the tests are divided into two subgroups called verbal and performance.

The tests in the children's scale recommended for use are as follows:

Verbal	*Performance*
(1) General information	(6) Picture completion
(2) General comprehension	(7) Picture arrangement
(3) Arithmetic	(8) Block design
(4) Similarities	(9) Object assembly
(5) Vocabulary	(10) Coding or mazes

Wechsler advises using the digit span test (not listed above) and the tenth test, coding or mazes, as supplementary tests if time permits or conditions warrant substituting them.

General Aptitude Test Battery

This test is one of the first designed as a new approach in the field of vocational aptitude testing. In the past it has been the custom to give a separate test for each aptitude. This method frequently took much time and was inclined to wear out the client as he labored through separate instructions, separate booklets, etc. The General Aptitude Test Battery is designed to measure ten aptitudes with one test. The GATB has the added advantage of presenting uniform norms for all the aptitude scores. Prior to it each test had been standardized on different groups and the scores of one test were not always related in a meaningful way to the scores of another test.

The GATB is the product of more than ten years of research by the United States Employment Service. It was completed in 1947. The use of the GATB is controlled by the Federal Government and the test is not for sale to private individuals or agencies.

There are fifteen tests in the General Aptitude Test Battery. These tests are combined to give scores for ten aptitudes. Some of the tests are paper-and-pencil tests while others require apparatus and equipment.

The paper-and-pencil tests may be given to groups or to individuals, while the apparatus tests can be given to only one person at a time. Thus the GATB is partially an individual-test battery and partially a group-test battery.

The ten aptitudes derived from the fifteen tests are as follows:

G—Intelligence
V—Verbal aptitude
N—Numerical aptitude
S—Spatial aptitude
P—Form perception
Q—Clerical perception
A—Aiming, or eye-hand coordination
T—Motor speed
F—Finger dexterity
M—Manual dexterity

Differential Aptitude Test

This battery of tests designed by the Psychological Corporation and published in 1947 is intended primarily for use with high-school students. The Differential Aptitude Test (DAT), like the General Aptitude Test Battery, is devised to incorporate many aptitude tests in one battery and to present comparable norms for its tests.

In the DAT there are seven tests used to measure eight different abilities. Not all of these are aptitudes, as will be seen; some are achievement tests. The tests are as follows:

(1) *Verbal reasoning.* The test is designed to measure ability with words and consists of exercises in verbal analogies. The vocabulary is fairly elementary. In an analogy exercise (——— is to father as daughter is to mother) there is a reasoning factor also involved, which makes the DAT verbal-reasoning test somewhat like a combination of the Thurstones' verbal-meaning and reasoning factors in their Primary Mental Abilities Test.

(2) *Numerical ability.* The test measures ability to grasp numerical relationships in problem situations which minimize language. The problems require computational ability rather than the ability to read a written problem and then compute the answer. This DAT test is akin to the Thurstones' number factor.

(3) *Abstract reasoning.* The test measures reasoning ability without using words by employing a spatial type of problem. A series of geometric figures is changed according to an underlying principle that the testee must reason out. This type of problem has been used frequently in the American Council on Education Psychological Examination. College students may remember this if it was part of their entrance test battery. The abstract-reasoning test attempts to measure the same ability as the Thurstones'

(4) *Space relations.* The test is designed to measure the same ability as the Thurstones' space factor. It requires the mental ability to manipulate forms and to imagine how an object would appear in three dimensions if it were rotated. It is a clever test and approaches the problem of measuring spatial ability via paper and pencil in a new manner.

(5) *Mechanical reasoning.* The testee is asked to figure out the method by which a simple mechanical device or apparatus is working and then at a certain point to predict its motion or declare an underlying principle of physics. This is very similar to the Bennett Mechanical Comprehension Test. The test covers achievement as well as any spatial aptitude that the testee may have.

(6) *Clerical speed and accuracy.* The test attempts to measure speed and accuracy of seeing and marking similarities in letter and number combinations. This test is also a combination of achievement in these skills and some factors of eye-hand coordination.

(7) *Language usage.* This last test has two subtests within it: spelling and sentences. The sentences subtest measures rules of grammar, punctuation, etc.

Summary

Although we may not all agree on a definition of intelligence, agreement is probably universal that all of us have some intelligence and that it is very important in our daily lives. For the purposes of this paper intelligence has been defined in terms of problem-solving.

Binet's empirical (building upon the facts) approach to intelligence has been discussed. Stern's adaptation of the Binet mental-age technique by deriving a mathematical ratio called the intelligence quotient was also critically examined. The thesis was presented that the I.Q. does not reveal sufficient information regarding our intelligence to be of most practical use in the light of what we now know.

Other theories of intelligence were examined in a partially historical and developmental approach. The theories of five people—mathematicians and/or psychologists—were selected for study. Starting with Stern's (c.1911) uni-factor theory, the following theories were also studied: Spearman's (1904) two-factor theory, Thomson's (1916, 1935, 1948) sampling theory, Thorndike's (1905, 1914, 1926) multi-factor theory, and the Thurstones' (1938) multiple-factor theory. The last has also become widely known as the theory of primary mental abilities.

The importance and usefulness of the primary-mental-abilities approach was then emphasized, and a sample test of these abilities included for the interest of the reader.

Other methods of measuring mental abilities were also presented because of their wide use and their dependence on the concept of primary mental abilities. These methods were: the Army General Classification Test (AGCT); the two tests by David Wechsler, the Wechsler-Bellevue Intelligence Scale (W-BIS) and the Wechsler Intelligence Scale for Children (WISC); the General Aptitude Test Battery (GATB); and the Differential Aptitude Test (DAT).

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